REMARKS

Applicants respectfully request reconsideration and withdrawal of the outstanding Office Action rejections based on the foregoing amendments and following remarks. Claims 14-24 have been amended and claims 27-30 have been added. Support for the amendments can be found on page 1, 2nd paragraph, in the paragraph bridging pages 5 and 6, and page 12, lines 8-21 of the specification. No new matter has been added.

Response to Objections to the Drawings

The Examiner has objected to the drawings because the Examiner contends that Figure 4 does not show the appropriate band structure of the quantum dots. Applicants submit that the enclosed replacement figure indicates the direction of the stacking direction and shows the conduction band edge of the nanostructures. Moreover, Figure 4, as amended, removes the physical nanostructures from the band diagram. Accordingly, Applicant respectfully request reconsideration and withdrawal of this objection.

Response to Rejections under 35 U.S.C. §112

Claims 14-26 have been rejected under 35 U.S.C. §112, second paragraph, as being indefinite. The Examiner asserts that the lateral direction is unclear. Applicants submit that claim 14 has been amended to clarify the meaning of lateral direction. Applicants submit that there is clear disclosure on page 1, paragraph 2 of the specification that the lateral direction is perpendicular to the stacking direction of the

layers. Thus, Applicants have incorporated this language into the rejected claims to clarify the meaning of "lateral". Accordingly, Applicant respectfully requests reconsideration and withdrawal the rejections under 35 U.S.C. 112, second paragraph.

Response to Rejections under 35 U.S.C. §102

Claims 14-25 were rejected under 35 U.S.C. §102(b) as being anticipated by Holonyak (US Published Patent Application No. 2003/0059998). The Examiner contends that Holonyak discloses each and every element of present claims 14-25. More specifically, the Examiner contends that Holonyak discloses a quantum well structure for the absorption or emission of photons comprising a quantum well layer arranged between two barrier layers, wherein at least one of the barrier layers comprises nanostructures which compensate or modulate a lateral homogeneity of the barrier layer which is present without the nanostructures wherein the quantum well layer is the absorption or emission layer. Applicants respectfully disagree.

Holonyak discloses a QD-QW structure ([0035] for Fig. 8), for which there is no mention of optical transitions in the QW. Moreover, it is explicitly stated that optical transitions take place in the QDs ([0006], [0007], Fig. 9, Fig. 13)- "the invention makes it possible for the charge to get unstuck from a QD and move from dot to dot in the waveguide region to help optimize emission." ([0006] of Holonyak). Holonyak does not teach a structure with QDs and QW, characterized in that the QW layer is in the form of an absorption or emission layer for the absorption or emission of the photons.

Paragraph [0008] describes a structure with a QW layer only in the form of a transport layer.

Holonyak has two distinct ideas running through his application:

1) optical transitions occur in the QDs using a QW that serves as an auxiliary connecting layer [0006]. The QW layer is repeatedly, through the application, referred to as "auxiliary", hence, it is auxiliary to the actual optically active region.

2) QDs are used as improved doping sources, either for QD lasers [0011] or for transport devices where the transport (not optical transition!) is taking place in the QW [0008]. The auxiliary QW layers are even optional, and do not necessarily need to be used (last sentence of [0008]). Thus, if Holonyak's structure does actually include QWs, the QWs are only used to transport carriers to QDs wherein emission or absorption occurs. Conversely herein, the carriers (electrons) tunnel from QW to QW and emission or absorption occurs therein.

Holonyak discloses quantum dots that are separated from a quantum well by a barrier layer having a thickness of between 5 and 100 Angstroms (see paragraph [0013]). Paragraph [0007] of Holonyak states "Also, should the QDs not collect injected electron-hole pairs efficiently (a distinct possibility), the thin auxiliary QW layer (or, if necessary or desirable, multiple QW layers) will collect the injected carriers and feed them via resonant tunneling into the quantum dots to then scatter the carriers down to the lower energy dot states for recombination (for photon generation and laser operation)." Thus, Applicants submit that, in Holonyak, the purpose of the quantum dots is to use their high density of states to capture electrons and holes to feed into the quantum well, coupled to the quantum dot layer via tunnelling through the barrier.

The presently claimed invention is configured opposite to the normally occurring relative order of energy levels as follows: InAs QDs are small, and the is QW wide, therefore the relative energy levels are opposite to those for the most commonly used cases such as Holonyak.

The description of QDs and QWs as being narrow or wide refers to them being higher or lower, respectively in the lowest-confined particle state, which in real space means that the QD and QW layers are 1) made from different materials and/or 2) have differing thicknesses (thin corresponding to "narrow" and thick corresponding to "wide"). Therefore, the lateral dimensions play the smallest role in determining energy levels. The higher states of QD are resonant with and couple by tunneling to lower states of the QW layer [0006, Holonyak]. QDs are used in order to introduce material combinations which, in configurations other than QDs would contain crystalline imperfections precluding lasing. Holonyak aims to improve the optical transitions within the QDs. The QW material would contain crystalline imperfections if the same material combination and the same thickness as for the QDs are used. The present invention is configured differently and the presently claimed method uses the QWs for a different purpose than Holonyak. The structure of Holonyak is configured for field effect transistors, not optical transitions. Therefore, the QW:QD energy levels are the opposite as those herein.

Accordingly, Holonyak does not mention intersubband transitions. Holonyak mentions only interband transitions (involving both valence and conduction band) and, therefore, does not benefit from any possible disorder. Thus, Holonyak's invention is completely different because the present invention is configured to deliberately contain

disorder, in order to get vertical emission from intersubband transitions, which are otherwise forbidden by parity. Therefore, in the present invention, the carriers are confined in the QW and not in the QD because $E_{QW} < E_{QD}$. In Holonyak, the carriers are confined in the QD because $E_{QD} < E_{QW}$.

With regard to the materials used in the structure, the Examiner states "applicants quantum dot are of a lower energy than the barrier as well." Applicants agree and point out that the invention does not purport to have QDs with bandgap larger than the barriers. Indeed it is the function of a barrier to separate two regions from each other so that electrons in each of the two separated regions are impeded in moving to the other region. Therefore, by definition, a barrier energy level will be larger than the lowest energy levels of the regions around it. Contrary to Holonyak, herein the structure is configured so that $E_{QD} > E_{QW}$. Therefore, in the presently claimed structure, the carriers do not collect in the nanostructures; rather, the carriers tunnel through the barrier layer, which comprises nanostructures arranged such that said nanostructures cancel or modulate a homogeneity of said quantum well layer extending in at least one lateral direction in the absence of said nanostructures, <u>without substantially influencing energy values in said quantum well layers</u>. Thus, while in the structure disclosed by Holonyak, the carriers are fed from the quantum wells down to the lower energy dot states, in the presently claimed structure, as amended, the nanostructures do not affect the energy values of the carriers in the quantum well layers.

In Holonyak the QDs are the important active areas where, for example, the optical transitions take place, with the lowest minimum energy levels. But because there are not enough QDs, <u>Holonyak introduces the QW</u> (structure) in order to feed carriers

(electrons) to the QDs. In the presently claimed invention, the QW is the active area where, for example, optical transitions take place, with the lowest electron energy states unaffected by the wells. The QDs are introduced in order to modify the behavior of the QW by breaking translational symmetry. Therefore, the present invention is configured with energy levels of QDs and QWs opposite to that of Holonyak.

The examiner asserts the structure of Holonyak inherently influences energy values in said quantum well layer. Applicants submit that because Holonyak does not relate to intersubband devices, symmetry breaking has no relevance to Holonyak. Symmetry breaking is only relevant to intersubband devices. Thus, in the present invention contrary to Holonyak, the valence band is not involved in the transition, only the conduction band. Furthermore the configuration of the present invention is so that the energy levels in the QW are lower relative to the QD, and remain unchanged, then the transitions will continue to take place in the QW (after adding QDs, as compared to the QW device alone). Thus, this configuration allows the QDs in the barrier layer to break translational symmetry without having transitions take place in the QD.

According to the enclosed declaration signed by one of the inventors, Dr. William Ted Masselink, the presently claimed structure is configured so that carriers transition from a high energy state to a low energy state <u>in the quantum wells</u> and the nanostructures are configured so that their bandgap is larger than the bandgap of the quantum well so that <u>the nanostructures do not substantially influence energy values in said quantum well layers</u>. Dr. Masselink states that rather than being the low energy collection sink for carriers as in Holonyak, in the present invention the quantum dots are configured so that they cancel or modulate a homogeneity of said quantum well layer

extending in at least one lateral direction in the absence of said nanostructures without substantially influencing energy values in said quantum well layers. Thus, by keeping the carriers in the quantum wells, rather than in the quantum dots as in Holonyak, the present structure allows better control of the carriers' energy.

Further, Dr. Masselink states that at the time of filing, one of skill in the art would know that if nanostructures, e.g. quantum dots, were present in a quantum well structure, and the nanostructures did not substantially influence the energy levels of the electrons in the quantum wells, then those nanostructures would have larger bandgap than the band gap of the quantum wells. Thus, because the presently claimed structure requires that the nanostructures cancel or modulate a homogeneity of said quantum well layer extending in at least one lateral direction in the absence of the nanostructures, without substantially influencing energy values in the quantum well layers, the claimed structure requires nanostructures with bandgaps that are higher than those of the quantum wells.

Thus, contrary to the structure of Holonyak, the nanostructures required by present claim 14 are part of the barrier layer and are configured to break the translational symmetry, thus allowing photons with electric-field vector perpendicular to the surface to couple to intersubband transitions. These nanostructures do not substantially influence energy values in said quantum well layers and do not act as electron sinks.

This distinction is further supported by the fact that the nanostructures in the presently claimed structure do not cancel or modulate the homogeneity of the quantum well structure itself (see page 12, lines 25-28). This is because the nanostructures do

not substantially influence the energy values of the carriers in the quantum well layers. However, in Holonyak, because the quantum dots collect the carriers, their presence will inherently influence the homogeneity of the structure as a whole depending on the position of the quantum dots.

Therefore, present claim 14, as amended, recites features which are not contemplated, suggested, or anticipated by Holonyak. The presently claimed quantum well structure is configured such that after emission of a photon from an electron, said electron goes from a high energy level to low energy value in a quantum well layer and such that after absorption of a photon by an electron, said electron originates in a low energy level in a quantum well layer. Holonyak only discloses transitions occurring in the QDs. Thus, whereas in Holonyak the QDs are the active areas and the QWs are auxiliary and optional, herein the QWs are the active areas and the QDs serve an auxiliary purpose. Also, the presently claimed structure contains nanostructures that cancel or modulate homogeneity of the quantum well layers extending in at least one lateral direction in the absence of said nanostructures, without substantially influencing energy values in said quantum well layers. In Holonyak, the nanostructures (QDs) do not cancel or modulate homogeneity of the quantum well layers, but rather the QDs collect electrons fed in from higher energy level QWs.

For at least the aforementioned reasons, Applicant respectfully submits that Holonyak does not anticipate each and every element of present claim 14. Moreover, claims 15-25 depending from claim 14, are not anticipated for at least the above reasons. Accordingly, Applicant respectfully requests reconsideration and withdrawal of the outstanding 35 U.S.C. 102(b) rejection.

Response to Rejections under 35 U.S.C. §103

Claim 26 stands rejected under 35 U.S.C. 103(a) as being allegedly unpatentable over Faist (*IEEE J. of Quantum Electronics*, v. 38, No. 6, June 2002, pages 533-546) in view of Holonyak (US Published Patent Application No. 2003/0059998). The Examiner contends that Faist teaches a quantum well cascade laser, but does not teach the quantum well structure of present claim 14. The Examiner relies on Holonyak for a disclosure of using quantum dots as a source of carriers. The Applicant respectfully disagrees with the Examiner's contention and submits that the Examiner has not established a prima facie case of obviousness for at least the following reasons.

As outlined above, Holonyak does not disclose that the quantum well structure is configured such that after emission of a photon from an electron, said electron goes from a high energy level to low energy value in a quantum well layer and, further, that after absorption of a photon by an electron, said electron originates in a low energy level in a quantum well layer. Also, the presently claimed structure contains nanostructures that cancel or modulate homogeneity of the quantum well layers extending in at least one lateral direction in the absence of said nanostructures, without substantially influencing energy values in said quantum well layers.

Therefore, the combination of Faist and Holonyak would lead to a quantum cascade laser (from Faist) that comprises a quantum well structure having low bandgap quantum dots to collect the electrons. Furthermore, there is no teaching or disclosure in either of Faist or Holonyak for a quantum well structure configured essentially in an opposite manner than that which is disclosed in the disclosure Holonyak. Thus, the

combination of Holonyak and Faist would not suggest to one of ordinary skill in the art how to arrive at a quantum cascade laser having a quantum well structure as is presently claimed. Thus, Applicant submits that the disclosure of Holonyak does not cure the noted deficiencies of Faist or vice versa. Accordingly, Applicant respectfully requests reconsideration and withdrawal of the outstanding 35 U.S.C. 103(a) rejection.

New Claims

New claims 27-30 have been added to define further embodiments of the invention. Support for these claims can be found on page 1, 2nd paragraph, in the paragraph bridging pages 5 and 6, and page 12, lines 8-21 of the specification. In Holonyak, the nanostructures (QDs) do not cancel or modulate homogeneity of the quantum well layers, but rather the QDs collect electrons fed in from higher energy level QWs (see, e.g. paragraph [0043]) which states "carriers are captured predominantly by the QW and then relax quickly to the ground state of the QW, and tunnel (see S.L. Chuang and N. Holonyak, Jr., Appl. Phys. Lett. 80, 1270 (2002)) into and recombine at the QDs)." Holonyak states that emission is optimized when the charge goes from dot to dot (see, e.g. paragraph [0006] and [0028]). Thus, the structure of Holonyak is not configured so that the emission takes place in a quantum well as recited herein. Furthermore, Holonyak is not configured to allow intersubband transitions, does not contain means for absorbing or emitting photons from an electron undergoing an intersubband transition in quantum well layers, or means for cancelling or modulating homogeneity of electron density distribution in said quantum well layers without

substantially influencing said energy values of the quantum well layers. Therefore, Applicants submit that claim 27 is distinguished from Holonyak.

Method claims 28-30 are also not anticipated by Holonyak for the above reasons and importantly because Holonyak does not disclose or suggest the method of allowing electrons to undergo optical transitions in quantum well layers.

Conclusions

In view of the foregoing amendments and remarks, Applicants respectfully request withdrawal of the outstanding Office Action rejections. Early and favorable action is awaited.

The Director is authorized to charge any fees or overpayment to Deposit Account No. 02-2135.

Respectfully submitted,

By

Robert B. Murray
Attorney for Applicants
Registration No. 22,980
ROTHWELL, FIGG, ERNST & MANBECK, P.C.
Suite 800, 1425 K Street, N.W.
Washington, D.C. 20005
Telephone: (202)783-6040
Facsimile: (202) 783-6031

RBM/AH
Enclosure: Declaration of Dr. Masselink
1653928